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We investigate the performance of Filter Bank Multi-Carrier (FBMC)-based dual-hop Amplify-and-Forward (AF) and static Decode-and-Forward (DF) in the context of Multiple access relay networks. We show that, in the context of Professional Mobile Radio (PMR) communications and their implementation constraints, AF protocol is more suitable than DF one. In fact, the former protocol requires low complexity and just a single receive antenna at the relay node rather than two for the latter. Furthermore, we show that AF and DF protocols present almost similar BER performances in the case of a relay with a single Transmit antenna for both ZF and MMSE equalizers.

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On the performance of FBMC-based AF and DF Multiple Access Relay Networks

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***Abstract*—We investigate the performance of Filter Bank Multi-Carrier (FBMC)-based dual-hop Amplify-and-Forward (AF) and static Decode-and-Forward (DF) in the context of Multiple access relay networks. We show that, in the context of Professional Mobile Radio (PMR) communications and their implementation constraints, AF protocol is more suitable than DF one. In fact, the former protocol requires low complexity and just a single receive antenna at the relay node rather than two for the latter. Furthermore, we show that AF and DF protocols present almost similar BER performances in the case of a relay with a single Transmit antenna for both ZF and MMSE equalizers.**

I. Introduction

PMR are currently used for low-rate data transmission like voice communications. This is due to the limited throughput resulting from the small frequency bands used by these systems [1]. Recently, there is a trend to upgrade the PMR networks to support high-rate applications and broadband services, by fitting a novel broadband data service within the scarcity (which is the European case) of available spectrum devoted to PMR systems [1], [2].

Due to their modularity, flexibility and their robustness against the channel selectivity, multicarrier techniques such as OFDM or Filter Bank based MultiCarrier (FBMC) rise as one of the most attractive candidates that can achieve very high data rates. However, coexistence and cohabitation with the primary deployed and active PMR systems is one of the major issues to introduce new broadband data services. Thanks to the good frequency localization achieved by filter bank waveforms compared to OFDM ones, FBMC systems have been demonstrated to fit perfectly the primary PMR-TEDS harmful interference protection requirements [3].

Moreover, in PMR networks operating in 380-400 MHz, 410-430 MHz or 450-470 MHz bands, implementing Multiple Input Multiple Output (MIMO) systems is very complicated due to various issues like additional space, weight and wind loading [4]. Thus, multiple access relaying schemes could provide a good alternative to conventional MIMO systems. The aim of this paper is to investigate the performance and the suitability of FBMC based Multiple Access Relay Channel (MARC) to PMR networks. Two of the most commonly used relaying protocols: Amplify-and-Forward (AF) and Decode-and-Forward (DF) are considered.

The rest of this paper is organized as follows: The system model is described in Section II. We then develop a brief theoretical analysis of Multiple access AF (MAF) and Multiple access DF (MDF) strategies in Section III. Furthermore, the MAF and MDF performances are evaluated in Section IV. Finally, we give some concluding remarks and future perspectives in Section V.

II. System Model

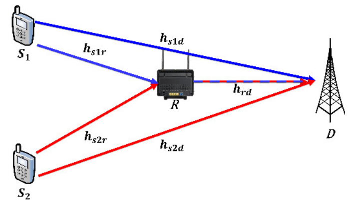

Fig. 1. Uplink of PMR multiple access relay network

In this section, we consider the uplink of an FBMC based PMR multiple access relay network that consists of two source transmitters $\mathbf{S}_1$ and $\mathbf{S}_2$, a half-duplex relay node $\mathbf{R}$ and a destination receiver $\mathbf{D}$. All nodes are equipped with a single transmit/receive antenna except the relay in the DF case which needs two receive antennas to decode the signals of both sources. The key idea of the considered multiple access relaying schemes is that the base station $\mathbf{D}$ becomes, with the help of the relay, able to decode the signals coming from both source transmitters.

The communication between $\mathbf{S}_{j,\, j=1,2}$ and $\mathbf{D}$ is achieved with the help of $\mathbf{R}$ in two time slots. In the first one, both sources transmit their respective signals. Then, $\mathbf{R}$ implements its relaying protocol on the superposition of the received signals and transmits the resulting signal to $\mathbf{D}$ during the second time slot. It is worth mentioning that during this period, both sources remain silent.

III. Analysis of MAF and MDF strategies

A. *MAF strategy*

In this protocol, $\mathbf{R}$ amplifies and forwards the superposition of both received signals to $\mathbf{D}$ during the second period. After FBMC demodulation of both signals (from direct and indirect links), the destination $\mathbf{D}$ can apply linear equalization on each subcarrier like in FBMC based spatial multiplexing (SM) MIMO systems [5]. To this end, we can write for the m_0-th subcarrier and the n_0-th time interval $t=n_0T/2$, (T is the symbol period),

$$\mathbf{y}_{\mathbf{d}m_0,n_0}=\mathbf{H}_{\mathbf{af}m_0}\left(\mathbf{a}_{m_0,n_0}+j\mathbf{u}_{m_0,n_0}\right)+\mathbf{n}_{\mathbf{d}m_0,n_0}, \qquad (1)$$

where, $\mathbf{y_d}_{m_0,n_0}$, $\mathbf{a}_{m_0,n_0}$, $\mathbf{u}_{m_0,n_0}$ and $\mathbf{n_d}_{m_0,n_0}$ are, respectively, the demodulated signal, the input data, the intrinsic interference due to FBMC waveforms and the noise vectors. Moreover, the channel matrix $\mathbf{H_{af}}_{m_0}$ is given by:

$$\mathbf{H_{af}}_{m_0} = \begin{bmatrix} H_{s1d} & H_{s2d} \\ \beta_{\mathrm{af}} H_{rd} H_{s1r} & \beta_{\mathrm{af}} H_{rd} H_{s2r} \end{bmatrix} \tag{2}$$

where H_{rd}, H_{sjr}, H_{sjd} are the channel frequency gains at subcarrier m_0 for **R - D**, $\mathbf{S}_j$-**R**, and $\mathbf{S}_j$-**D** links, respectively. β_{af} is a normalization factor defined as,

$$\beta_{\mathrm{af}} = \left[P / \left(\sigma_r^2 + P \sum_{j=1}^{2} \sum_{i=0}^{L-1} |h_{sjr}(i)|^2 \right) \right]^{1/2} \tag{3}$$

σ_r^2 and P are the noise variance at **R**, and the signal transmit power, respectively. $|h_{sjr}(i)|^2$ is the power gain of the $i-th$ path of the $\mathbf{S}_j$-**R** link channel, and L is the number of paths.

B. MDF strategy

In this relaying scheme, **R** listens during the first time slot, and jointly decodes the signals from both sources. This protocol is called "static" because **R** always tries to decode the received signal even for low SNR, which may propagate the errors and lead to bad performance in that case. During the second time slot, **R** forwards the superposition of the FBMC modulation of the decoded signals. Assuming a perfect data recovery at **R**, **D** obtains after demodulation,

$$\mathbf{y_d}_{m_0,n_0} = \mathbf{H_{df}}_{m_0} (\mathbf{a}_{m_0,n_0} + j\mathbf{u}_{m_0,n_0}) + \mathbf{n_d}_{m_0,n_0}, \tag{4}$$

where $\mathbf{H_{df}}_{m_0}$ is given by,

$$\mathbf{H_{df}}_{m_0} = \begin{bmatrix} H_{s1d} & H_{s2d} \\ H_{rd}/\sqrt{2} & H_{rd}/\sqrt{2} \end{bmatrix}, \tag{5}$$

IV. Preliminary Results

In Figure 2, we investigate performance of both protocols: MAF, MDF with a single receive antenna at **R**. Comparing the different curves related to ZF equalization, one can see that both strategies provide almost the same performance. Moreover, the MAF diversity gain is slightly less than one due to the fact that the channel gains related to the indirect link follow the product of two Rayleigh random variables. Furthermore, an improvement of almost 2 dB is achieved by MMSE compared to ZF equalizer. In order to evaluate the impact of the noise at **R**, we have compared the different schemes to the optimal case ($\sigma_r^2 = 0$). We can see that the latter outperforms the others particularly in low SNR regime.

Figure 3 investigates the performance improvement provided by the utilization of **R** equipped with 2 transmit antennas compared to the previous one with a single one. This improvement can be explained by the fact that the channel gains of the indirect link in the 2 transmit antennas case are uncorrelated, offering additional degree of freedom compared to the single transmit antenna one in which both streams experience the same channel gain.

V. Concluding Remarks

The proposed multiple access relay schemes present an alternative solution to the problem of implementing a MIMO system in PMR base stations. In fact, with the help of the relay node, MAF protocol with a single transmit/receive antenna at each node, is equivalent to an SM MIMO system. Unfortunately, the MDF scheme is not suitable since the relay needs at least 2 receive antennas in order to decode the source's messages. In future perspectives, a second receive antenna will be considered at the destination node in order to improve the diversity gain and a performance analysis of diversity/complexity will be investigated.

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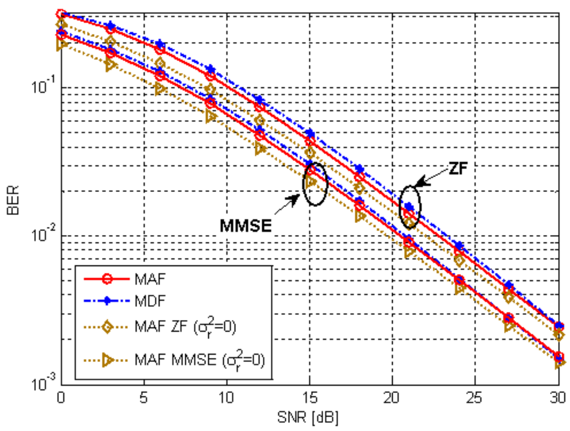

Fig. 2. MAF and MDF performances with a single transmit antenna at **R**

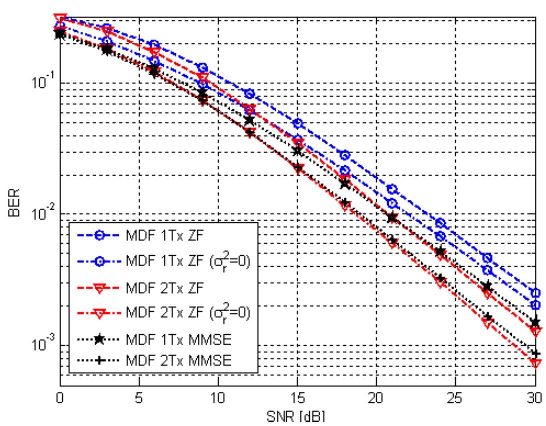

Fig. 3. MDF performances: 1 transmit antenna vs 2 transmit antennas at **R**